Benthic Resuspension by Internal Wave Stimulated Global Instability

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LONG-TERM GOAL

The goal of this work is to contribute toward an understanding of how long internal waves on the shelf region affect the optical properties of the water column and issues related to remote sensing of the coastal ocean.

OBJECTIVE

Our work is directed toward providing a mechanistic understanding of and a predictive basis for processes whereby long internal waves interact with and stimulate resuspension from the bottom boundary. We also seek to provide insight regarding the effect of long internal waves on the vertical distribution of sedimentary and biological particles in the water column, and how the distribution of these particles impact remote sensing of motions and processes on the shelf region.

APPROACH

Our approach is to develop an understanding of resuspension and particulate transport processes by means of theoretical modeling and numerical simulation. We also interact with field and laboratory investigators and collaborate on data analysis, model validation, and interpretation of results.

WORK COMPLETED

Analysis of topographic resonance for internal waves in sheared currents, together with the associated boundary layer structure, has been analyzed for various realistic thermoclines. The models of structured thermoclines provide a useful basis for a climatology study of long internal wave packets. Theoretical modeling and numerical simulations of the boundary layer dynamics under a particular class of long internal waves in shallow seas has been completed, and the relation of these dynamics to sediment resuspension has been explored. Analysis of a number of striking resuspension events captured in the CMO data set has been completed and possible correlations to the numerical simulations of global instability in the wave-induced boundary layer are in progress. In addition, analyses and simulations have been completed which reveal the capacity for long internal waves to contribute to the formation of thin layers of near-buoyant particles.

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14. ABSTRACT
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15. SUBJECT TERMS

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RESULTS

The coupling between long internal waves and the bottom boundary layer has been examined in considerable detail for one class of waves, namely, those associated with resonant topographic generation and propagation against an oncoming shear flow. This case was selected for initial study because it mimics the class of internal-wave/boundary-layer interaction where definitive evidence of elevated rates of resuspension stimulated by long internal waves was reported (cf., Bogucki et al, JPO, 27:1181-1196, 1997). The boundary layer under the footprint of a solitary wave of elevation is found to exhibit a sudden onset of a peculiar dynamics (a global instability) as the wave amplitude exceeds a threshold value. The global instability in the boundary layer creates regions of coherent vortex structures and locally steep gradients in the bottom stress. We find that critical wave amplitudes required to stimulate global instability in the boundary layer, which is a fully nonlinear dynamics, decrease quite rapidly as the boundary layer Reynolds number increases, and that the coherence of the unsteady dynamics persists to quite high super-critical conditions (cf., Wang& Redekopp, 2001). Characterization of the boundary layer dynamics at higher Reynolds numbers and consideration of other types of wave packets is continuing.

We have examined extensive records in the CMO data set and have identified several important features coincident with episodic bursts of resuspension. A number of remarkably strong resuspension events have been identified and analyzed. These events are correlated with long internal wave packets, generally propagating against the tidal current. We have also noted the concurrent presence of both mode-1 and mode-2 internal waves in a number of episodes with significant resuspension. In addition, we have noted the presence of mode-2 and pronounced peaks in resuspension under conditions when the polarity of longwaves switches from that of depression to elevation (due to the deepening of the mixed layer by strong, persistent surface wind events). The latter observation is also consistent with the resuspension – global instability mechanism developed and applied in our studies

In recent work we have identified, by a detailed examination of a month-long record of the CMO 96 data set, a 'general climatology' of the tidally-generated field of long internal waves on the shelf. This climatology appears to be quite persistent, but was found to be interrupted and strongly modified when strong storms pass the outer reaches of the shelf region and interfere with the nominal wave field. This general climatology is illustrated in Figure 1. A segment of a longer portion of the data record is amplified in the figure. The amplified segment shows the arrival of a mode-1 packet, followed by the appearance of mode-2 waves, followed by a surface-wave-dominated signature. The horizontal velocity structure associated with the wave field (after the long-term mean has been subtracted) is shown for different short-term records in the bottom of the figure. There are not only significant elevations in the Beam-C signature associated with the arrival of the mode-1 waves, but also when mode-2 waves appear. One also observes clear increases in the magnitude of the near-bottom, low-frequency currents when packets dominated by both of these modes passes the instrumented tripod.
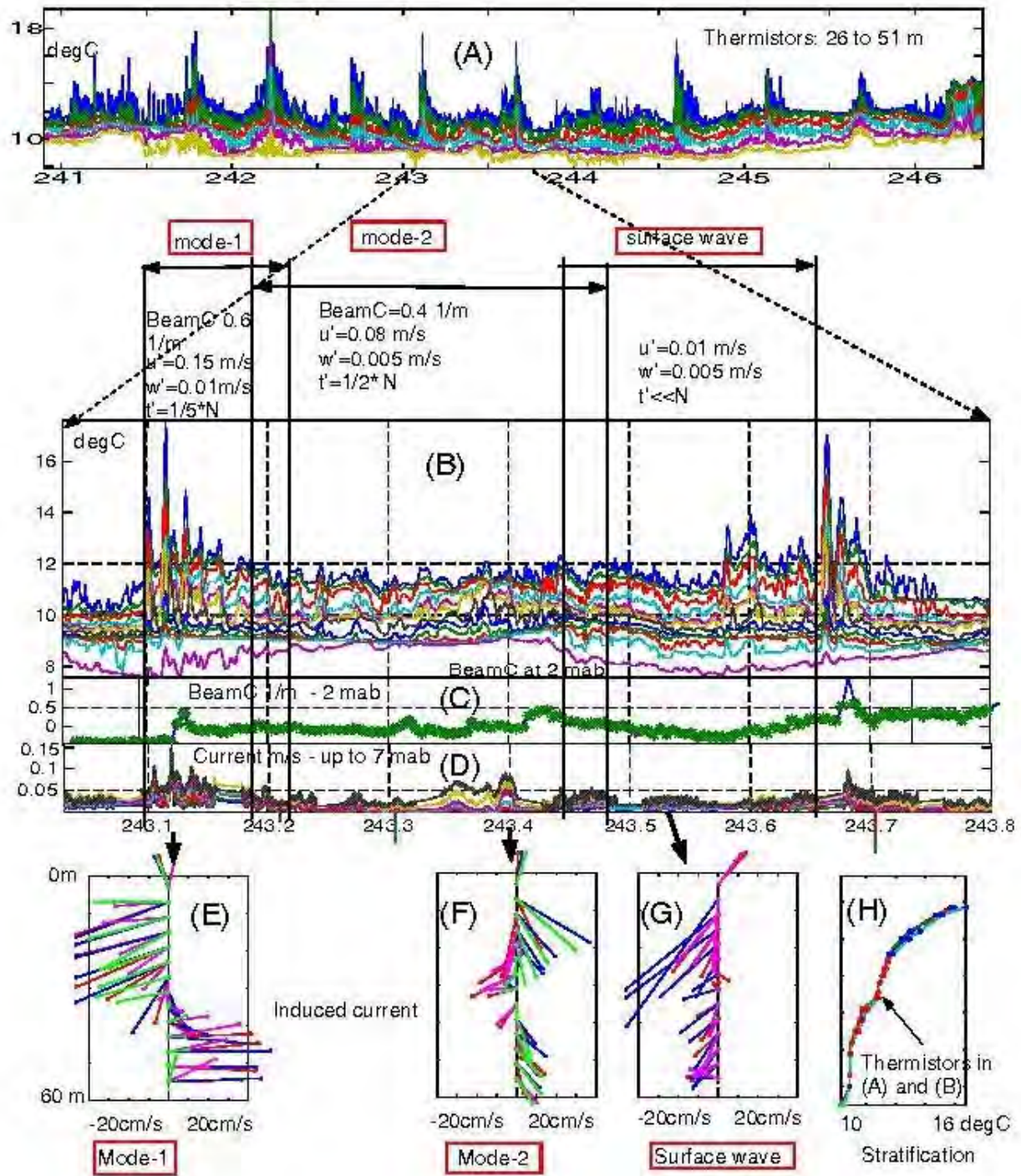
Figure 1.

In further work, we have examined the consequence of propagating packets of long internal waves on the concentration of particulates distributed in the water column. Our results show that the passage of a wave packet can create distinct layers with dramatically reduced vertical scale containing locally enhanced concentrations of near-buoyant particles, especially those whose particle Reynolds number is of order one or larger so that their motion is described by a nonlinear drag law (cf., Wang et al., JGR, 2001, to appear). We believe that these results may have particular relevance to issues of remote sensing and the coupling of internal waves and biology.

RELATED PROJECTS

In a related project we have developed and tested an evolutionary model for long internal waves in the presence of a background baroclinic seiche (cf., Horn et al., 2000). We show that the energy exchange between the seiche and the packet of long internal waves is profoundly affected by relative phase relationships of the seiche and packet. The model is being validated against laboratory data from the Centre for Water Research at the University of Western Australia. One aspect of this work is the development of a rapid calculation tool for characterizing the weakly nonlinear internal wave field in closed basins (cf., Horn et al., 2001, to appear in JFM). These results have relevance to the prediction of benthic resuspension by long internal waves in semi-closed seas and lakes. This work has also been extended recently to provide a consistent, weakly nonlinear model of the internal wave field generated by time-varying surface wind stresses.

IMPACT

The mechanism whereby long internal waves can give rise to elevated rates of resuspension is believed to have applicability to other wave-related events as well where temporally-varying fields interact with surface boundary layers. In this sense, the current effort might lead to a better understanding of the resuspension process in other flow contexts. Certainly the consequences of the spatio-temporal hydrodynamic processes being studied in this effort for particulate transport and the creation of layers of elevated concentration of particulates is believed to be of particular significance for optics and remote sensing.

RELATED PROJECTS

We have been interacting with the Orange County Sanitation District, and participating in a field experiment, in relation to the role of internal waves and tides on bacterial transport in the vicinity of Huntington Beach, south of Los Angeles. Preliminary results point to a prominent role of long internal waves in onshore transport.

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